SPECIFICATION

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ELECTRONIC ELIMINATION OF STRIATIONS IN LINEAR LAMPS

Background of Invention

[0001]   The present invention is directed to improving the visual appearance of linear fluorescent lamps, and more particularly, to the elimination of visual striations which may occur in gas discharge lamps. Generally, a gas discharge lamp will have an elongated gas-filled tube having electrodes at each end. A voltage between the electrode accelerates the movement of electrons. This causes the electrons to collide with gas atoms producing positive ions and additional electrons forming a gas plasma of positive and negative charge carriers. Electrons continue to stream toward the lamp's anode and the positive ions toward its cathode sustaining an electric discharge in the tube and further heating the electrodes. The electric discharge causes an emission of radiation having a wavelength dependent on the particular fill gas and the electrical parameters of the discharge.

[0002]   A fluorescent lamp is a gas discharge lamp in which the inner surface of the tube is coated with a fluorescent phosphor. The phosphor is excited by the ultraviolet radiation from the electric discharge and fluoresces, providing visible light.

[0003]   During operation of a gas discharge lamp, such as a fluorescent lamp, a phenomenon known as striations can occur. Striations are zones of light intensity, appearing as dark bands. This phenomenon can give a lamp an undesirable strobing effect. An example of the striation phenomenon is shown in FIGURE *1* , which depicts a linear fluorescent lamp *10* employing Krypton added as a buffer gas to improve the efficacy of the lamp. In FIGURE *1* , lamp *10* has striation zones *12* which appear as the dark bands moving along the length of the lamp. Striations in gas discharge lamps are known to occur in cold applications and in other contexts such as Krypton content lamps.

[0004]   A variety of theories as to why striations occur have been set forth. For example, in U.S.

Patent No. 5,001,386 to Sullivan, it is stated that striations are believed to occur as a result of high-frequency currents re-enforcing a standing wave of varying charge distribution between the lamp electrodes.

[0005]   Sullivan attempts to solve the striation problem by injecting a dc component superimposed on top of a driving ac current. A disadvantage to this technique is that, by adding the dc bias, it is possible to cause damage to the lamp by moving mercury in the lamp to one end, creating an unbalanced light output. It has also been suggested that increasing the crest factor in a lamp lighting system will eliminate the usual striations. However, increasing the crest factor may also increase the stress on a lamp, which will lead to a shorter lamp life.

[0006]   Therefore, it would be beneficial to provide a ballast that solves the above-described problems without adding a dc bias and without substantially increasing the crest factor.

Summary of Invention

[0007]   The present invention provides a ballast circuit powered by a system power source. The ballast is in operative connection with the system power source wherein the ballast is designed to convert the AC system power source to a DC voltage on a DC bus included within the ballast circuit. An inverter circuit is included in the ballast circuit in operative connection with the DC bus to generate an asymmetric alternating current on a lamp input line. Further, a gas discharge lamp is in operative connection to the lamp input line, configured to receive the asymmetric alternating current, thereby eliminating visual striations otherwise occurring in the lamp.

Brief Description of Drawings

[0008]   FIGURE 1 illustrates a typical fluorescent lamp having striation zones creating a strobing effect to an end user;FIGURE 2 illustrates a standing pressure wave in a closed organ pipe;FIGURE 3 depicts a high-level view of a system implementing the concepts of the present invention;FIGURE 4 illustrates a preferred embodiment of the present invention;FIGURE 5 depicts an input forcing function obtained by use of the concepts of the present invention compared to a standard forcing function;FIGURE 6 depicts a lamp input current obtained by use of the concepts of the present invention compared to a standard lamp input current; and FIGURE 7 illustrates an alternate embodiment of the present invention.

Detailed Description

[0009]   As depicted in FIGURE *1*, the striation zones *12* generate an undesirable visual effect to an end user. In addressing this problem, the inventors applied a null hypothesis to describe the striation phenomenon, and propose the physics behind striations can be modeled as a standing pressure wave *14* in an enclosed organ pipe *16*, such as shown in FIGURE *2*. The frequency of resonance for a closed pipe is given by:

[0010]

$$f_n = \frac{n}{4l}\sqrt{\frac{\frac{C_p}{C_v}P_0}{\rho_0}}$$

[0011]   where l is length unit, n is harmonic, c_p is molar capacity as constant volume, c_v is molar capacity at constant pressure, P_0 is undisturbed gas pressure and D_0 is density of gas outside compression zone.

[0012]   Using this hypothesis, it has been determined that striations in a lamp can be reduced or eliminated by operating a ballast having an inverter at other than a 50% duty ratio. That is, in a two switch inverter, for example, one switch is configured to operate longer than the remaining switch. As long as this offset in the duty ratio is blocked, such as by a capacitor, no DC current will flow through the lamp"s arc. Rather, for example, the positive portion of the of the lamp current cycle will have a shorter duration but a higher amplitude than the succeeding negative portion of the cycle, or vice versa. Consequently, a ballast circuit has been developed which provides an asymmetric input current to the lamp. By altering the symmetry of the current in this manner, the repetitive resonance frequencies which are believed to create the striations are interfered with thereby eliminating the visual appearance of striations.

[0013]   FIGURE *3* sets forth an exemplary lamp lighting system *20* which incorporates the concepts of the present invention. An input power source *22* supplies power to a ballast *24*. Ballast *24* includes an AC-to-DC converter *26* which provides a DC voltage on DC bus *28* which, in turn, provides power to a lamp input current generating circuit *30*. The lamp input current generating circuit *30* is configured to generate an asymmetric alternating current on lamp input line *32* that provides power to gas discharge lamp *34*. In one embodiment, the lamp input current generating circuit *30* can be an inverter circuit or portions of the inverter circuit, and

will be described primarily with this focus. However, it is to be appreciated that other components and circuits capable of generating or supplying an asymmetric alternating current to lamp *34* may also be used. These additional circuits, which may be represented by block *30* of FIGURE 3, may or may not be part of the inverting circuit. For example, a sub-circuit subsequent to the inverting mechanism can be used to alter asymmetric generated signal into an asymmetric form.

[0014]

Set forth in FIGURE 4 is one embodiment of inverter circuit *30* suitable for incorporating concepts of the present invention. Inverting circuits of this type are well known in the industry and, therefore, the circuit will not be described in great detail except where concepts of the present invention are implemented. The circuit comprises complementary switches *40* and *42*, bipolar junction transistors in this exemplary embodiment. The emitters of switches *40* and *42* are connected in common to a series configured resonant circuit *44* including capacitor *46* and inductor *48*. A blocking capacitor *50* is connected to the remaining end of resonant circuit *44* and is series connected to lamp *34* at node *52* with the remaining end of lamp *34* connected to the junction of capacitor *46* and inductor *48* at node *54*. A feedback inductor *56*, a tap from inductor *48*, is connected to the common emitters of switches *40* and *42* at node *58* with the remaining end of inductor *56* series connected to driving inductor *60* which is connected, in turn to feedback capacitor *62*. The remaining end of feedback capacitor *62* is connected to the base terminals of switches *40* and *42*. A first resistor *64* is connected from the base terminals of switches *40* and *42* to the collector terminal of switch *40* which is also connected to the positive lead of DC bus *28* at node *66*. The collector terminal of switch *42* is connected to ground *68* which is connected to the negative lead of DC bus *28* at node *70*. Driving inductor *60* is bridged by output clamping circuit *72* comprising back-to-back, series connected zener diodes *74* and *76*. Capacitor *78* bridges resonant circuit *44*, and resistor *80* is connected between node *58* and ground *68*. Reverse-conducting diode *82* bridges the emitter and collector terminals of switch *40*, with the cathode of diode *82* connected to the collector terminal of switch *40*. Reverse-conducting diode *84* bridges the emitter and collector terminals of switch *42*, with the anode of diode *84* connected to the collector terminal of switch *42*. A preferred method of producing asymmetry in the lamp input current for the circuit illustrated in FIGURE 4 is to configure switches *40* and *42* with mismatched *hfe* (commonly called beta). This causes the transistor with a lower *hfe* to conduct for a shorter period of time, thereby causing the on time of switches *40* and *42* to be asymmetrical. That is, one BJT will conduct for a

shorter period of time than the other will.

[0015]   FIGURE 5 shows an asymmetrical forcing function *86* of the present invention compared to a typical symmetrical forcing function *88* of prior art ballast inverters. The forcing function is a voltage as measured from node *58* with respect to node *52* in FIGURE 4. The particular forcing function shown is configured to have a short positive duration and a long negative duration. The positive and negative durations can be reversed with equal efficacy.

[0016]   FIGURE 6 illustrates the effect of asymmetrical forcing function *86*. Asymmetrical load current *90*, measured as the current flowing from node *54* to node *52* is shown in the lower half of FIGURE 5, and can be compared to a symmetrical load current *92* shown in the upper half of FIGURE 6. The positive portion of the asymmetrical current cycle is of shorter duration than the negative portion of the cycle, however, the positive portion is of a higher amplitude than the negative portion. Symmetrical load current *92*, however, shows equal positive and negative durations, and equal positive and negative amplitudes. There is no DC component to asymmetrical load current *90* because DC current is blocked by blocking capacitor *50*.

[0017]   An alternate embodiment of the present invention is shown in FIGURE 7 incorporating MOSFET switches *94* and *96*. With continuing reference to FIGURE 4, like numbered numerals in FIGURE 7 designate similar components. Omitted in FIGURE 7 are reverse-conducting diodes *82* and *84* since MOSFET switches *94* and *96* have intrinsic reverse-conducting diodes. Added in FIGURE 7 are gate voltage limiting zener diodes *98* and *100*. The BJT switches of FIGURE 4 did not require voltage limiting diodes because the base-emitter junction of a BJT inherently limits the input voltage.

[0018]   In a prior art inverter incorporating complementary MOSFET switches, voltage-limiting zeners *98* and *100* would be configured with equal component voltage ratings. However, in this alternate embodiment of the present invention, zener diodes *98* and *100* are configured with unequal voltage ratings. The unequal voltage ratings cause one of switches *94* and *96* to be in an on state longer than the opposite switch. The effect of unequal on times of switches *94* and *96* will be the same as illustrated in FIGURES 5 and 6 for BJT switches *40* and *42*.

[0019]   The beneficial aspect of the asymmetric input line current generated by asynchronous switching of inverter circuits begins to be noticed when even small on/off time imbalances are generated. It is to be noted however, that as the on/off times between, for example, the two

switches in the described circuits are increased, a circuit's crest factor will also increase, diminishing the circuit's efficiencies. Therefore, in practical applications users will determine the benefits versus tradeoffs obtainable to provide the most efficient circuit having striations eliminated.

[0020]   The embodiment shown in FIGURE 4 and the embodiment shown in FIGURE 7 are for exemplary purposes only. It is to be appreciated that other configurations can be imagined that that fall within the scope of the present invention.

[0021]   As previously noted, while the present invention may be implemented in numerous forms. In the forgoing embodiments, component designations and/or values for the circuits of FIGURES 4 and 7 would include:

[0022]

[t1]

Transformer Inductor 48 (56 is a tap from 48)	3.5mH
Transformer Inductor 60	150uH
Capacitor 46	1nF, 1kV
Capacitor 62	100nF, 50V
Capacitor 50	100nF, 500V
Capacitor 78	120pF, 1kV
Diodes 82, 84 each	1N4937
Zener diode 98	9V
Zener diode 100	11V
Zener diodes 74, 76 each	24V
Resistor 64	1 Meg
Resistor 80	1 Meg
Transistor 40	General Electric 13003
Transistor 42	General Electric 93003
Transistor 94	IRF310
Transistor 96	IRF9310

[0023]   It is to be appreciated that, while a variety of lamps may be used, for the values presented, the present lamps would operate on a power supply of line 120 / 277 Vac at 60 Hertz cycle where the lamps may be a gas discharge lamp such as rare gas filled T8 linear fluorescent. The components listed as STM components are from STMicroelectronics of Catania, Italy. Although the present invention is described primarily in connection with fluorescent lamps, the circuit herein described may be used to control any type of gas discharge lamp. Since certain changes may be made in the above-described circuit without departing from the scope of the invention herein involved, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted in an illustrative and not a limiting sense.